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ABSTRACT

This report summarizes the background data, proceedings, conclusions and recommendations of a conference on the role of the liberal arts colleges in the education of chemists. The conference considered the relative advantages of undergraduate education in chemistry at liberal arts colleges and universities. The role of the colleges in contemporary chemical education was summarized on the basis of quantitative data when that was available, and otherwise on the basis of the consensus of opinion of the conferees. Four invited speakers contributed statements on the preparation of graduates of the colleges for graduate study at a university, and on the problems of "quality" and "have not" colleges. The informal consensus of the conference in a number of areas for which no supporting data are available are presented as statements in response to questions which emerged as the focus of concern throughout the discussion. These statements are followed by discussion of some alternatives to the traditional undergraduate program. The conference also prepared recommendations on faculty, instrumentation and its maintenance, and curriculum. The report concludes with a list of problems on which data are inadequate, and which are sufficiently important to justify serious additional study. (LC)

ED0 40049

THE ROLE OF THE LIBERAL ARTS COLLEGES IN THE EDUCATION OF CHEMISTS

A Report of a Conference Sponsored by the ADVISORY COUNCIL ON COLLEGE CHEMISTRY in Chicago, Illinois; January, 1967

The Conference on "The Role of the Liberal Arts Colleges in the Education of Chemists" was organized and chaired by Professor Edward L. Haenisch of Wabash College. A survey of chemistry departments in the colleges was carried out and reported to the Conference by Professor Arthur F. Scott of Reed College. This report was written by Professor Robert I. Walter of the University of Illinois at Chicago Circle.

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Department of Chemistry, Stanford University, Stanford, California 94305

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SUMMARY

This report summarizes the background data, proceedings, conclusions and recommendations of a conference on the role of the liberal arts colleges in the education of chemists sponsored by The Advisory Council on College Chemistry in January of 1967. The conference was convened because of a pervasive feeling that the liberal arts colleges today face a crisis of identity and purpose; it is not certain that these institutions will continue to serve chemistry as well in the future as they have in the past. The conference considered the relative advantages of undergraduate education in chemistry at liberal arts colleges and universities. The role of the colleges in contemporary chemical education was summarized on the basis of quantitative data when that was available, and otherwise on the basis of the consensus of opinion of the conferees. Four invited speakers contributed statements on the preparation of graduates of the colleges for graduate study at a university, and on the problems of "quality" and "have not" liberal arts colleges. The informal consensus of the conference in a number of areas for which no supporting data are available are presented as statements in response to questions which emerged as the focus of concern throughout the discussion. These statements are followed by discussion of some alternatives to the traditional undergraduate program which might be more suitable for some institutions. Finally, the conference prepared recommendations on faculty, instrumentation and its maintenance, and curriculum. It commented on the role of the ACS Committee on Professional Training in upgrading undergraduate education in chemistry. It also presented a proposal for a survey of the needs and necessary resources for the support and improvement of undergraduate education in chemistry. Finally, it prepared a list of problems on which data are inadequate to reach conclusions, but which are sufficiently important to justify serious additional study.

The approach of the conference to some of the problems considered is indicated by the quotations from this report which are given below.

"The problem of the colleges is to become more competitive in affording professional opportunity for the faculty, while at the same time preserving their devotion to the conscientious discharge of teaching duties at the undergraduate level. Mere imitation of the universities is not adequate here; the colleges need to make original contributions to the solution of their problems." (p. 19).

". . . it seems to this conference that the attempts of some graduate schools to require the same quite intensive undergraduate education in chemistry of all entering students is unwise and mistaken . . . For every 'graduate' department willing to single out for criticism the students who come to it from the colleges, another can be found which claims to prefer graduates from the better colleges as candidates for graduate study." (p. 16).

". . . there is serious question whether the colleges are meeting their own professed educational objectives in offering curricula designed to fulfill these increased expectations of the graduate schools. In many colleges, these pressures have discouraged the free innovation in curriculum which should characterize a good undergraduate liberal arts college, and which should be a major contribution of these institutions to the educational process . . . It seems clear that students . . . have been repelled by the inflexibility of the undergraduate chemistry curriculum." (p. 16).

The participants in the conference "are concerned by the evidence that many colleges do not now offer adequate preparation for graduate work, and by their expectation that the demands of the graduate schools will become more stringent in the future . . . They feel that it is essential for each of these institutions to reexamine its performance, capabilities, and goals as realistically as possible. Each should then choose a course of action which is compatible with its capabilities and goals, with the honest recognition that deficiencies in some areas may make it impossible to provide a full range of undergraduate courses at a level competitive with the strongest institution." (p. 18).

I. INTRODUCTION

The contributions in years past of private colleges to the education of chemists have been widely recognized. In recent years, however, there has been increasing criticism of the undergraduate education in science offered by many of these institutions. Although this criticism has been voiced most frequently by faculty members in those institutions to which graduates of the colleges go to earn a Ph.D. degree, there have been voices of self-doubt in the colleges themselves, and among the private foundations and government agencices which have provided financial support to them. The question being asked in all seriousness in these quarters is *whether the development of chemistry has moved this discipline beyond the capabilities of the private colleges to offer adequate undergraduate education in competition with chemistry departments in the Ph.D.-granting institutions.*

This question is not being asked in chemistry alone. Pake[1] first presented the case that the physics major who is graduated from a private college is inadequately prepared to compete with graduates of the universities in his subsequent graduate work. Later reports by the Committee on Physics Faculties in Colleges[2, 3] concluded that only some 30 of over 600 undergraduate institutions which grant a bachelors degree with a major in physics offer a program which can be considered adequate preparation for graduate study in that field, and listed recommendations which are designed to upgrade to acceptable levels the major program in some 300 additional undergraduate institutions.

Clearly the situation has not deteriorated to this degree in chemistry, since the Committee on Professional Training of the American Chemical Society, in response to invitations from the presidents of the institutions involved, has evaluated and approved the programs offered by nearly 140 (The number changes from year to year; this is the 1965 figure.) private colleges to prepare the chemistry major for professional work in chemistry. However, the total number of institutions of all types which offer the bachelors degree with a major in chemistry exceeds 900. (See Fig. 1.) Of these, nearly 160 (in 1965) offer the Ph.D. degree in chemistry, while the remaining institutions offer degrees in chemistry only through the masters level. Of the latter group, some 200 are either colleges supported by some unit of government (state or local), or private technical institutions, and are not the concern of this report. *We are concerned with the remaining 550 institutions, all of them private colleges, nearly 400 of which offer programs which have not been approved by the Committee on Professional Training.* (Later in this report it will be more convenient to use for statistical purposes an arbitrary classification which contains all privately-supported institutions which offer a major in chemistry but no doctorate in that field. This group of institutions will contain a small number of privately-supported technical schools in addition to the traditional liberal arts colleges.)

(1) G. E. Pake, Am. J. Phys., **29**, 678 (1961).
(2) Committee on Physics Faculties in Colleges, "Report on Teaching Physics," Physics Today, **17**, 36, (May 1964).
(3) Publication R-186, Committee on Physics Faculties in Colleges, 335 East 45th Street, New York, N.Y., September 1965.

Table 1

POTENTIAL ADVANTAGES FOR QUALITY UNDERGRADUATE INSTRUCTION

AT THE UNIVERSITY:

1. A full range of instrumentation and library reference material is available in university departments.
2. Students with the desire and qualifications to do so can enroll in a wide range of advanced courses, undergraduate or graduate, in the university.
3. Contact of university undergraduates with faculty may be limited, but it involves men who are active professionally in their fields, and thus aware of the latest developments and in a good position to judge the probable directions of future progress.
4. There also is possible contact with graduate students and postdoctorals who are close to the undergraduates' age and attitudes. These contacts with young chemists already deeply involved in research can be highly stimulating.

AT THE PRIVATE COLLEGE:

1. The full concern of the college is undergraduate education, whereas the university divides the creative and imaginative energies of the faculty between the undergraduate and graduate programs.
2. There is direct contact between students and professional chemists in both lecture and laboratories. (This advantage may be offset by the heavy teaching loads required of most college faculty members, which make it difficult for them to keep up to date with professional developments.)
3. The colleges provide earlier recognition of ability in students without adequate background, and a better opportunity to salvage poorly prepared students.
4. Exceptional students can be identified earlier, and given extra attention within or outside the normal course program.
5. Undergraduate students can be involved more fully in research conducted with members of the senior staff. This research commands maximum prestige because it is not overshadowed by doctoral programs in the same institution.
6. Colleges have greater freedom to experiment with courses and curriculum. One consequence of this is the possibility for better coordination between the various courses of the chemistry curriculum.

COMPARATIVE INSTRUCTIONAL ADVANTAGES OF UNDERGRADUATE COLLEGES AND UNIVERSITIES

A comparison of the characteristics of colleges and universities which bear upon their instructional capabilities will be helpful in considering the contributions of these institutions to the education of chemists. These characteristics are summarized in Table I.

It is apparent that all of the advantages of departments in universities result from the presence there of graduate programs. Most of them could be equalled by the private colleges if adequate financial support were available. In fact, the extensive growth and development of university departments during the past twenty-five years would not have been possible without heavy federal support of graduate study and research. Similarly, it should be noted that none of the advantages of the undergraduate colleges listed in Table I other than the first is intrinsic to these institutions. The universities could offer equal services if they chose to devote the necessary human and financial resources to this task. It thus appears that the advantages of either class of institution are more the result of institutional custom than of conditions imposed by institutional structure.

Chemistry departments in the private colleges contribute to undergraduate education in other ways than by the preparation of professional chemists. One of these is the education of high school teachers. It appears that the best-known colleges do not make a major contribution in this direction; their graduates for the most part become professionals instead. The various state-

supported colleges and many of the less known private colleges turn out most of the teachers. Furthermore, many of the private colleges train a substantial number of premedical students. All of these must complete at least two years of chemistry courses, and a substantial fraction of them complete at least limited chemistry major programs.

CONTRIBUTIONS OF CHEMISTRY TO A LIBERAL EDUCATION

The private undergraduate colleges profess and to some extent succeed in exposing all of their students to each of the intellectual disciplines, including the sciences. Chemistry is an intellectual discipline, and one of the liberal arts. The tendency in some quarters to exclude from the liberal arts those disciplines which involve the use of scientific equipment and physical measurements is mistaken. A long tradition of science as a component of a liberal education dates back to the universities of the early Renaissance. The importance of science, including chemistry, in our contemporary civilization demands its inclusion in any program which professes to develop understanding of that civilization. This extremely important contribution to general education in the colleges is the clearest way to develop a sympathetic and informed attitude toward science within the general population. It will affect the future support of science, and the intellectual climate within which scientists must work. Few educational institutions have any more than limited success in this important area. It has been almost entirely neglected by the professional chemists. This neglect has been extremely shortsighted, in view of the growing dependence of basic science upon public understanding and support.

The private colleges educate chemists in the context of a very broad intellectual environment which provides exposure to most facets of our current culture. Much of this exposure occurs by contact with fellow students who are committed to other fields, rather than through formal class work. One result is a decreased focus on professionalism during the undergraduate years. It is noteworthy that many of the universities are trying to imitate this aspect of the environment of the undergraduate colleges by dividing their student bodies into small residential groups where students live, attend classes, and study in close contact within the group.

The growing demand for college-level education, and the substantial contribution which courses in chemistry and the other sciences can make to the education of the large fraction of the population which attends these institutions make it clear that the private colleges must continue to function and to offer courses in chemistry, quite apart from their contribution to the professional education of chemists. It is equally clear that the professional chemists should take a greater interest in these institutions than they have in the past, both in their own self-interest, and as a social contribution which no one else is prepared to make.

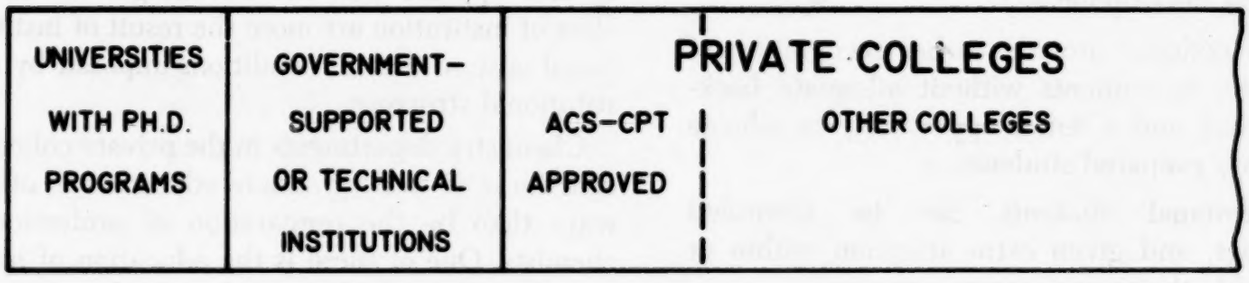

Figure 1
Classification of Institutions Which Offer Baccalaureate Training in Chemistry

II. DATA ON CHEMICAL EDUCATION IN THE COLLEGES

SOURCE OF DATA

In the summer of 1966, Professor Arthur F. Scott of Reed College conducted on behalf of AC_3 a survey by questionnaire of undergraduate institutions known to grant the baccalaureate degree with a major in chemistry. His questionnaire was mailed to some 700 accredited institutions on a list provided by the U.S. Office of Education. Institutions which offer a master's degree were included in the mailing, but institutions which offer the doctorate were excluded. Questionnaires were returned by from 55 to 70% of the institutions in the various categories which we shall describe below. A supplementary questionnaire was mailed to the chairman of 40 departments which grant the Ph.D. degree in chemistry, and replies were received from 29 of these. The responses to these two types of questionnaires constitute the primary source of data for this report, and were summarized for the panel by Professor Scott.[4] It is not known how the incomplete response may affect the data from these questionnaires.

CLASSIFICATION OF EDUCATIONAL INSTITUTIONS

The terms "college" and "university" are by no means used consistently on the American educational scene, but the former generally is applied to institutions with no professional schools and no degree above the masters. Institutions which do not grant the Ph.D degree have been divided for purposes of this report into two principal groups: privately-supported and publicly-supported colleges. The "private college" classification used here includes a few undergraduate technical institutions and others not usually considered to be liberal arts colleges. Each of these two main groups of undergraduate institutions has been subdivided further on the basis of two criteria: approval of the program of the chemistry department by the Committee on Professional Training (CPT) of the American Chemical Society, and production of baccalaureates who have gone on elsewhere to obtain the Ph.D. degree in chemistry during the nine years 1957 through 1965. All departments approved by the CPT have also produced one or more graduates who have earned the Ph.D. during the reference period. A second group of departments without CPT approval has nevertheless produced one or more graduates from each department who have earned the doctorate. A third category of institutions has neither received approval by the CPT nor produced any graduates who have earned the doctorate in chemistry in nine years.

The data gathered by Professor Scott apply separately to both privately-supported and publicly-supported colleges. For the most part, we choose to include in this report only the data for the privately-supported colleges, for several reasons. First of all, these include most of the institutions which are normally thought of as belonging to the category of liberal arts colleges, and few others. There are a substantial number of these institutions, and a substantial fraction of the questionnaires were returned by them. There are fewer publicly-supported colleges and the percentage of questionnaires returned by this group was lower, so the results are less reliable for these institutions. Furthermore, there are indications that few publicly-supported colleges can survive current pressures to provide for mass education. The number of public institutions which gave only the baccalaureate degree was 164 in 1951, but only 99 in 1964. Most of these institutions had at that time moved only so far as to give the master's degree, but it seems clear that most of them look toward eventual development of graduate programs through the Ph.D. Consequently, we consider their classification as colleges to be a transitory affair, and for the most part will confine our attention to the privately-supported undergraduate institutions. We shall assume during the subsequent discussion that this category is identical to the group of traditional private liberal arts colleges with all that this term may imply about the educational philosophy, goals, and methods of this class of institutions.

Since the basic question with which we are

(4) A full report of the results of his survey will be published separately by Professor Scott.

concerned is the ability of the private liberal arts colleges to compete with undergraduate programs offered by universities in the education of chemists, it will be necessary to compare institutions in these two categories where appropriate data are available. The Directory of Graduate Research[5] for 1965 lists 156 chemistry departments which offer the Ph.D. degree in chemistry. Of these, over 50 departments are so new, or have maintained such small graduate programs that they are not listed in the recent study of graduate education sponsored by the American Council on Education.[6] The 96 institutions whose chemistry departments were included in that study were divided into 60 which offer highly rated doctoral programs, and another 36 which were not grouped in the study. These ratings afford a rough division of graduate institutions into Group I (doctoral programs rated highly), Group II, (institutions listed but not rated highly), and Group III, (institutions with small or recently-begun Ph.D. programs in chemistry).

Partial data on the three categories of private and publicly-supported colleges and of universities are collected in Table 2, which gives the number of institutions in each category, the number of 1961 chemistry baccalaureates, and the number of Ph.D.'s awarded to graduates of these institutions during the nine-year period 1957 through 1965.

(5) Committee on Professional Training, American Chemical Society, "Directory of Graduate Research"; American Chemical Society, 1155 Sixteenth Street, N.W., Washington, D.C. Third edition, 1965.

(6) A. M. Cartter, "An Assessment of Quality in Graduate Education," American Council on Education, Washington, D.C., 1966.

Table 2

CATEGORIES OF INSTITUTIONS WHICH AWARD THE BACCALAUREATE DEGREE WITH A MAJOR IN CHEMISTRY

	Private Colleges			Public Colleges			Universities			
	Approved by CPT; graduates with Ph.D.	Not CPT approved; graduates with Ph.D.	Not CPT approved; no grads with Ph.D.	Approved by CPT; graduates with Ph.D.	Not CPT approved; graduates with Ph.D.	Not CPT approved; no grads with Ph.D.	I Rated	II Not Rated	III Not Listed	Totals
Number of institutions in category (in 1966)	137	245	143	33	108	40	60	40	56	862
Percent of all schools in category	15.9	28.5	16.6	3.8	12.4	4.7	6.9	4.7	6.5	100
1961 chemistry majors, baccalaureate level										
men	1025	983	170	463	635	122	1321	571	697	5987
women	244	297	183	89	108	40	260	137	115	1473
total	1269	1280	353	552	743	162	1581	708	812	7460
Percent 1961 chemistry majors contributed by each category	17.0	17.3	4.7	7.4	10.2	2.2	21.3	9.6	10.9	100
Chemistry Ph.D.'s awarded 1957 thru 1965 with undergraduate origin listed	1770	1126	0	683	460	0	3391	968	917	9315
Percent chemistry Ph.D's awarded 1957 thru 1965 with undergraduate origin listed	19.1	12.1	0.0	7.3	4.9	0.0	36.4	10.3	9.9	100
Annual chemistry Ph.D.'s per 1961 baccalaureate in chemistry (male + female)	0.156	0.099	0.00	0.137	0.069	0.0	0.246	0.147	0.124	
1957 - 1965 average annual chemistry Ph.D.'s per thousand male baccalaureates in all fields in 1961	8.4	5.7	0.0	—	—	—	6.5	4.4	3.6	

PRODUCTIVITY OF CLASSES OF EDUCATIONAL INSTITUTIONS

The last two rows of entries in Table 2 are the results of two different schemes for evaluating the productivities of the various categories of schools of undergraduate origin of chemists. The first of these gives the productivity of chemistry Ph.D.'s per chemistry baccalaureate awarded by that department; clearly the universities of all types excel on this basis. The last row of entries in Table 2 gives the number of Ph.D.'s (averaged over the period 1957 through 1965) who originated from each category of institution per thousand baccalaureates granted to men by that institution. The private colleges excel on this basis. The figure is similar to the "productivity index" defined and used by Knapp and Goodrich[7] in their study of the undergraduate origins of scientists, but in our case it is evaluated for chemistry only, rather than for seven sciences.

Both of these schemes for the quantitative evaluation of productivity have faults. The larger institutions (including most universities) as a rule offer specialized courses for students with various professional goals, including chemistry. There is consequently less chance that less highly motivated students will complete the full major in chemistry and then move directly into employment as chemists or otherwise without graduate study. Furthermore, there is less likelihood that premedical students will complete the preprofessional chemistry major; often these institutions provide a special major for premedical students. Consequently, the fraction of all students who major in chemistry will be small, but a large fraction of this select group in the universities will go on to do graduate work in chemistry. These notions probably explain the difference in the relative values of the parameters for the colleges and the universities.

(7) R. H. Knapp and H. B. Goodrich, "Origins of American Scientists," University of Chicago Press, Chicago, Ill., 1952.

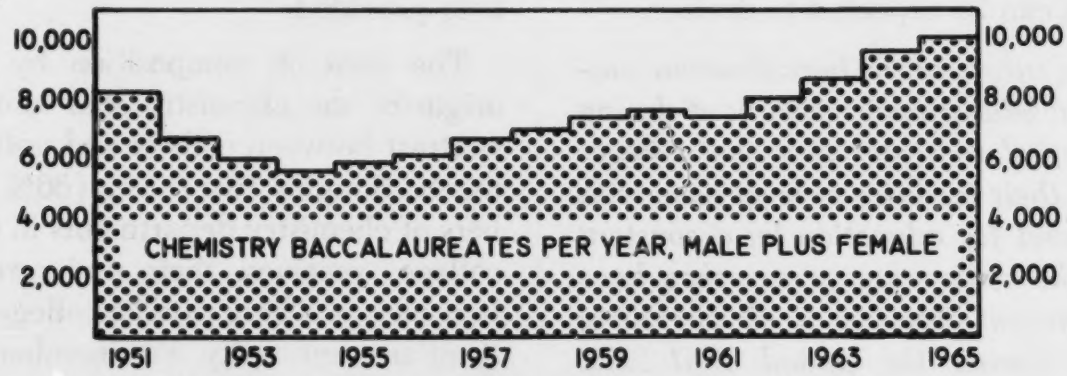

Figure 2
Annual Output of Chemistry Baccalaureates

SOURCES OF CHEMISTRY BACCALAUREATES

During the period 1951 through 1965, the yearly total number of baccalaureate degrees awarded in all fields has ranged from 287,000 to 589,000. The number in chemistry alone has ranged from a low of 5,800 to a high of 10,037, as shown in Figure 2. The distribution of all chemistry baccalaureates among private colleges, government supported colleges, and universities is given in Figure 3. It is striking that the fraction of chemistry baccalaureates produced by the privately-supported colleges has remained substantially constant through this period. On the other hand, the population aged 22 has also been constant (within 10%) from 1951 through 1962 with a rapid increase since 1963. Thus, the increase in the number of degrees awarded through 1962 is due to an increase in the fraction of the population which has obtained an undergraduate education, and since then to population growth. (The decrease from 1950 to 1955 represents tapering off of the various veterans' programs.)

There is grave doubt that the colleges can continue to expand in proportion to the virtual doubling of the college-age population expected by 1980. The decrease in the fraction of chemistry baccalaureates awarded by the colleges which began in 1964 suggests the trend which may be expected as the postwar population bulge reaches

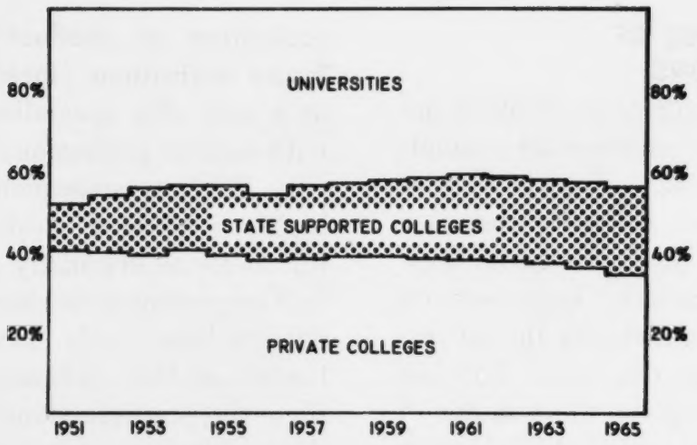

Figure 3
Distribution of Chemistry Baccalaureates By Type of Undergraduate Institution

college age. It seems likely that most of the expansion to meet the educational needs of this group will be carried out by publicly-supported institutions, including the two-year colleges. Consequently, if these assumptions are correct, the fraction of all baccalaureate degrees which will be awarded over the next decade by the private colleges can be expected to decline.

The foregoing survey of the baccalaureate output of American educational institutions during the postwar period indicates that the colleges have expanded their facilities to keep pace with the rising demand for education by a constant population in the college age group; they have produced a constant fraction of all chemistry baccalaureates during the period 1951-1962, while the population at age 22 was relatively constant.

THE QUALITY OF BACCALAUREATE PROGRAMS

We are not aware of any direct quantitative measure of the quality of an educational program. Most determinations of quality are based upon subjective evaluations by individuals whose opinions are widely respected. In Table 3 are collected data gathered by Professor Scott's survey of the chemistry departments in the private colleges, together with comparable data (where available) for the universities. These data apply to some of the commonly accepted indicators of the quality of an academic program. The general pattern for the colleges is the same as that described nine years ago in the report of the Wooster conference,[8] and subsequently in Professor Scott's study of the education of chemists in the United States:[9] the level of professional activity (research, writing, participation in meetings and institutes, etc.) of college faculty is related to the productivity of the institution, the quality of its students, and the adequacy of the facilities and supporting help provided.

The data on composition by baccalaureate origin of the chemistry staff affords a striking contrast between college and university departments. Roughly two thirds (66%) of the members of chemistry departments in the liberal arts colleges received their undergraduate educations at a public or private college, and only one third at a university. For members of university departments, these figures are reversed, and only one third (31%) received their undergraduate educations at a college. At the state-supported colleges, 58% of chemistry faculty members hold baccalaureate degrees from a college. For all academic chemists, the figure is 44%. These figures apply to all faculty age levels, so there has been no major shift in university faculty recruitment policies over the past 25 years. It is not known whether this distribution is the result of a selection process exercised by the chemistry departments making faculty appointments or by the candidates seeking academic employment.

(8) "Research and Teaching in the Liberal Arts College," a report of the Wooster Conference, the College of Wooster, Wooster, Ohio, 1959.

(9) A. F. Scott, "The Education and Training of Chemists in the United States," Part 4, Chemical and Engineering News, 43, 96-108 (14 June, 1965).

Table 3

COMPARISONS OF LIBERAL ARTS COLLEGES AND UNIVERSITIES

	Private Colleges			Universities		
	Approved by CPT; graduates with Ph.D.	Not CPT approved; graduates with Ph.D.	Not CPT approved; no grads with Ph.D.	I Rated	II Not Rated	III Not Listed
Number of institutions in category	137	245	143	60	40	56
Total staff members	809	955	472	1553	518	1026
Average number of staff per department	5.9	3.9	3.3	25.9	14.4	17.1
Average number of majors graduated per staff member in 1961	2.2	2.1	1.4	1.[illegible]	1.6	1.1
Age distribution of staff in percent, 1966						
under 30	17.9	21.4	24.4	6.6	5.4	3.0
30 - 40	34.1	36.0	29.4	36.5	36.0	34.3
40 - 50	26.3	21.6	24.8	25.8	24.3	26.9
over 50	21.7	21.0	21.4	28.3	29.4	25.8
Undergraduate origins of staff by age group, listed as percent college baccalaureates						
under 30	68	71	66	30	36	34
30 - 40	65	83	59	27	34	35
40 - 50	58	71	78	29	30	28
over 50	63	69	58	27	31	40
Average for institution category	63	71	63	28	33	34
A.C.S. meetings attended per staff member, 1963 - 1966	0.8	0.6	0.5			
Participation in undergraduate instructional scientific equipment program, 1962 - 1965						
number of schools applying	115	189	77	60	36	56
percent of schools applying	84	76	51	100	100	93
percent applications granted	75	60	40	72	66	60
average amount requested	14,500	7,300	6,900	17,900	17,300	17,900
average amount granted	9,700	6,000	6,200	15,000	13,000	11,700
Participation in N.S.F. undergraduate research participation program, 1959 - 1966						
number of schools applying	96	91	27	53	31	51
percent of schools applying	70	37	19	88	85	85
average amount requested	50,500	27,500	17,900	125,000	79,800	57,200
average amount granted	24,200	7,150	3,940	56,200	41,500	19,500
Participation of staff in N.S.F. programs for college teachers, 1959 - 1966, as percent of institutions reporting						
research participation	34	27	18			
conferences	35	20	16			
academic year institutes	1	5	3			
summer institutes	33	41	38			
supplementary training	1	4	6			
Average research support per institution	10,600	3,150	2,700			
Percent staff with Ph.D. degree, by discipline						
chemistry	88	70	56			
biology	76	70	48			
physics	72	45	41			
mathematics	46	25	16			
Percent institutions which offer physics major	100	70	29			
Average semester credit hours in chemistry taken by students who go to graduate school	41-45	36-40	36-40			

III. SUMMARIES OF PRESENTATIONS TO THE CONFERENCE BY INVITED SPEAKERS

PREPARATION FOR GRADUATE STUDY IN CHEMISTRY OF STUDENTS WHO ENTER THE UNIVERSITY OF ILLINOIS

by Herbert E. Carter

During recent years, many of us have developed reservations about the role of the liberal arts colleges in the undergraduate education of scientists. However, these colleges exist, they clearly are producing scientists, and they will continue to make this contribution. Our problem is to determine how to offer the best possible education to young people with the limited resources available to support educational facilities.

At the University of Illinois, approximately 100 entering graduate students have taken registration examinations each year over the past ten years. About 70% of these students have earned the Ph.D. degree. Some 15% of each entering group drops out by the end of the first year of graduate study (mostly for academic reasons), and another 15% leave after the first year, usually for non-academic reasons.

Performance on the registration examinations, which are designed to test at the level of a good undergraduate program in chemistry, indicates some inadequacies on the part of students who come to the University from the liberal arts colleges. More of these students fail all four examinations and fewer of them pass all four relative to the fraction they contribute to the group of entering students. On the other hand, grades at the end of the first year of graduate study, and ultimate performance on the Ph.D. thesis, bear little relation to the results on these placement examinations. The only generalization which seems supported by experience at the University of Illinois is that students from most of those colleges with fewer than four faculty members in chemistry do not overcome their deficiencies as well, and have more trouble throughout their graduate careers, than do students trained by larger departments. Some 900 institutions now give a bachelor's degree in chemistry. Of these, about 300 have fewer than four staff members in chemistry, and 100 of these have only one staff member.

During coming years it will be impossible with the available funds to remedy all inadequacies in all of the colleges. However, the current and expected rise in undergraduate enrollments will require the use of all adequate facilities for education at this level. It will be necessary to examine carefully the factors which make it possible for some colleges to turn out a high-quality product and to help other institutions to meet the same standards. Aid to these institutions must be based upon a rigorous, critical evaluation of their capabilities in the light of the factors which are known to enable some institutions to do a very good job. These factors seem to me to be the size and quality of the faculty, the number and competence of students, the quality of educational leadership in the institution, the nature of the curriculum, and the strength of supporting departments in mathematics and physics.

If the current expansion in undergraduate enrollments should produce a proportionate increase in the number of graduate students (this is by no means certain, on the basis of current projections), there will not be enough places for all applicants for Ph.D. training. This shortage will be aggravated by restricted budgets for teaching assistants and for research in the established graduate schools. Graduate training for one man through the Ph.D. level costs about $75,000. Our financial resources and facilities will have to be used more wisely in the future. We need better methods for predicting the success of graduate students who work for the Ph.D degree. There is serious question whether the modern Ph.D. is the relevant graduate degree for all students. Many chemists might be better prepared for careers in teaching or industry by a graduate program less completely directed toward research. To these people, the Ph.D. degree is merely a status symbol which is not essential to their careers, and a more flexible degree which offers training in teaching, business,

or industrial problems in addition to chemistry, as the interests of these students dictate, might offer better preparation for their subsequent careers.

The liberal arts colleges have not fully explored some current opportunities for support and for strengthened programs. They should consider cooperative arrangements with universities. They should weigh the possible use of funds now becoming available for applied or interdisciplinary programs such as weather modification, environmental studies, or oceanography. They should plan imaginative special programs adapted to the particular needs of their area; often these programs will be interdisciplinary in nature.

BACKGROUNDS OF GRADUATE STUDENTS IN CHEMISTRY AT THE UNIVERSITY OF ARKANSAS

by Arthur Fry

The sources of graduate students at the University of Arkansas are quite different from those of the University of Illinois. Very few of the Arkansas graduate students come in with a B.S. degree from a university, and those who do are usually from the lower half of their graduating class. Most of them come from liberal arts colleges and public undergraduate colleges in the surrounding area. Most of these institutions are not nationally known, and they produce graduates with a very wide range of quality. The lower-division offerings of these colleges range from adequate to very good. Many of them do not offer one or more of the upper-division courses essential to graduate study in chemistry.

The chemistry department at the University of Arkansas detects deficiencies in incoming students by entrance examinations and evaluation of undergraduate transcripts. The more extensive backgrounds of the university graduates show up clearly, even though these university graduates come from the low end of their classes. On the basis of these data the liberal arts and public undergraduate colleges which furnish our students clearly are not preparing them as well as we would like. Most of these students come to us a semester or more deficient in advanced undergraduate course work, which must be made up during the first year of graduate work.

It is difficult to assess the real potential of any but the best students from the small colleges in this area, either from their transcripts or from the results of entrance examinations. However the student's chance of obtaining an advanced degree at Arkansas is about nine out of 10 if he completes his first year with a B or better average in the required courses (and very low if he does not). The initial advantage of the university graduate seems to be completely gone after that first year. But it must be remembered that our comparison is of the above average graduates of colleges which often do not offer complete upper division programs with average or below average graduates of universities. Our few top graduates of universities are able to complete their advanced degree programs in record time.

We would like to have better prepared students, and we hope that steps can be taken to upgrade the staffs and facilities of the liberal arts and public undergraduate colleges in our area. But the attitudes of our department reflect the nature of our students. We recognize that most of our students will arrive deficient in upper division course work, and we give them time and encouragement to overcome these deficiencies. It may take a semester or a year longer to obtain a Ph.D. degree, but these "deficient" students very often have real aptitude for, and ability in,

chemistry. Good students of this type may be lost to the profession if their deficiencies are not either remedied by upgrading their undergraduate colleges, or recognized and remedied by a sympathetic graduate department. The second solution may be wasteful in terms of the total time required by a student to obtain an advanced degree, and in terms of university facilities and staff time, but to eliminate a student with good potential by getting him in over his head in a graduate program is even more wasteful.

Very few of the colleges which send students to the University of Arkansas have had any sort of undergraduate research programs, although that pattern is beginning to change. From our experience, it is clear that those students who have had a good academic year or summer of undergraduate research participation experience have a decided advantage of one or more semesters at the stage at which they choose to begin their Ph.D. research.

One place where we can see that the average small college graduate has an advantage over the university graduate is in teaching assistantship service. The university graduate usually has not had previous experience of this sort; the good small college graduate has, and is interested in the work.

THE "QUALITY" LIBERAL ARTS COLLEGES — AN IMPRESSIONISTIC REPORT

by Joseph D. Danforth

The better departments in the stronger liberal arts colleges have the greatest number of educational "problems." They aim to give their students a good start in chemistry without either boring or burying them. Those who continue for graduate work must be prepared for study at the top institutions. At the same time, the lower-division courses must be offered at a suitable level for premedical students, biology majors, and non-scientists who usually cannot be placed in separate sections. Finally, some appreciation of science must be provided as part of the liberal eduation of non-scientists. This last job is so badly done that it is a critical problem in most departments.

The crucial problem to staff members in the liberal arts colleges is to gain more time. Time is needed for study, for research, for reflection, for curriculum improvement, and for participation in community affairs. Pressures on faculty time have increased as the pace of chemical developments has accelerated. They have also been increased by the growth in instrumentation, with accompanying problems of instruction, maintenance, and upkeep. It seems clear that the problem of adequate time cannot be solved by attention only to teaching loads. Adequate provision should also be made for subprofessional help in the laboratory and stock room, in instrument maintenance, and secretarial service. The pressure of heavy demands on faculty time is reflected in most of the other problems which are discussed below.

It is not at all clear what sort of introductory course should be offered in chemistry today. How can it take proper account of changes in the high school curriculum, and of pressures from the graduate schools to incorporate additional material in the undergraduate program? What should be its coverage, and what should be the expected standards of student performance? How should it reflect current changes in the practice of chemical science?

The growth in instrumentation for chemical research poses a whole series of problems to the colleges. Can instruments in the $30,000-$50,000 range be justified in institutions which serve relatively small numbers of chemistry majors? How can instruments of this type be used effectively for the large lower-division classes? Should

they be available for general student use, or should they be limited to operation by a few specially qualified students? How should setup, operation, and maintenance be taken care of?

What is the proper place of research in the quality liberal arts colleges? In most of these institutions, staff members are expected to publish in the scientific literature. Furthermore, undergraduate majors are encouraged or required to carry out research problems during their senior year, and possibly during summer vacation. What is the proper amount and emphasis on research efforts by students and faculty in these institutions, and how does one provide moderate financial support, an adequate level of instrumentation and library resources, and reasonable exchange with scientific colleagues? Probably the colleges have not explored adequately the possibility of local industrial support of these programs. They should be attractive to industry because research at the undergraduate level might offer a sound means for attracting students to the type of work commonly done in industry.

Attraction of suitable students is a growing problem to the liberal arts colleges. In many high schools, prospective scientists are advised to go to universities in order to obtain an adequate undergraduate education. The liberal arts colleges get students who lack a clearly defined interest in science and who wish to explore a variety of fields before making a professional commitment. The long sequence of necessary courses in chemistry then requires that good prospects must be urged to take science courses during their freshman year. Some students are reluctant to begin a commitment this early. The colleges must make a greater effort to recruit top students. It is first necessary for us to satisfy ourselves that we can do a first-class job in competition with the universities for those top students who come to us.

The most urgent single problem for the liberal arts colleges is that of staff obsolescence. Fighting this requires time, motivation, and broadly-developed faculty interests. Most presently available course materials are not well suited for faculty self-help. Texts and professional publications in the scientific literature fail to fill the needs of an individual who must work by himself. There is a great need for self-study materials which are designed specifically for the renewal of interest and knowledge on the part of teaching chemists. In addition, there is need for wider recognition of the necessity for periods of formal refresher training for faculty members in the colleges.

THE "HAVE NOT" LIBERAL ARTS COLLEGES: WHAT NEXT?

by Samuel Massie

The liberal arts colleges in this category tend to be small institutions with fewer than four faculty members in chemistry. Few of these men will have the Ph.D. degree, and those who do may have a degree in education rather than chemistry. The institutions tend to be geographically isolated. Their buildings are inadequate, they have serious deficiencies in laboratory and library resources, and generally the supporting courses offered in mathematics and physics are very weak. Most of these instutions have negligible endowments. Many of them are church related, but some are former teachers' colleges which have retained state support during the conversion to liberal arts institutions. The faculties in these institutions are dedicated and very hard-working. Their duties are so heavy that there is no possibility that they can overcome their defiiciencies by independent reading, study, and research. Teaching loads in the range

of 18-25 hours a week are not uncommon, and as a rule there is no subprofessional help. Faculty salaries are frequently so low that it is necessary for staff members to find salaried employment during the summer to make ends meet. There are no leaves provided for study and self-improvement.

The students in these institutions occupy the middle to low ability range. Many of them come from families which can offer little or no financial help. Frequently the students are too poor to buy their own books. As a rule, they have gone to high schools which are inadequate, and they enter college with academic deficiencies which it would be difficult for the best institutions to overcome.

Buildings and laboratory facilities available in these institutions are usually grossly inadequate. As a rule they were not planned by chemists, and were not originally intended for laboratory use. Equipment available for student use in these institutions is very limited. Most of them cannot afford and do not have any modern spectrophotometric instruments. Library facilities are even worse. Many of them lack *Chemical Abstracts* and the *Journal of Chemical Education*, and most of them are deficient even in advanced reference textbooks. Supporting disciplines in these institutions generally are weaker than chemistry itself.

Sources of help for these institutions are not adequate. The National Science Foundation programs of summer institutes, fellowships, undergraduate research participation, teaching equipment grants, and visiting scientists provide most effective aid to those institutions which already operate at a higher level, and have more clearly thought out programs and purposes. The programs of the U.S. Office of Education have not yet developed far enough to indicate their usefulness. Institutional pairing schemes have been tried, but have not generally been successful.

What remedies, then, are available to these institutions? In most cases, for reasons both of institutional pride and student interest, they cannot be persuaded to give up the major program in chemistry. In these cases, a real service could be provided through a modified approved major program. This would not be designed to provide strong preprofessional training, and presumably should be under the supervision of a group different from, but analagous to the Committee on Professional Training. It would urge and help these institutions to provide a limited program at a high level. The fact of approval would be a major help in overcoming problems of institutional pride and prestige which otherwise lead these departments to attempt to do too many things and to do them badly. With the advantage of the prestige of a limited approved program, many of these institutions would find it possible to offer advanced work on a cooperative basis, or to urge their students to transfer to other institutions to complete a full preprofessional undergraduate major. Without the help and the endorsement of an outside agency, they will find it difficult to give up listing in their catalogues courses which they do not offer, or offering courses which they cannot teach at an adequate level.

Discussion of these institutions must be based upon the assumption that they will continue to exist. They will not close down because there is demand for their services, and there are no other institutions available to provide these services at a cost or level which makes them accessible to the students they serve. One can hope for gradual improvement in their offerings, and one must search for ways to aid in this improvement.

IV. CONCLUSIONS

These conclusions represent the informal consensus of the Conference in a number of areas for which no supporting data are available. Indeed, the nature of some of them is such that it would be impossible to obtain quantitative verification. They are presented here in the form of statements in response to questions which emerged as foci of concern throughout the discussion.

QUESTIONS WHICH MUST BE ANSWERED BY THE COLLEGES

Have the Liberal Arts Colleges a Clear View of Their Identity and Purpose?

Some current problems of the liberal arts colleges arise from a crisis in identity and purpose in these institutions themselves. The historical role of the undergraduate college has been the development of both character and intellect in its students. Prior to 1900, most of these institutions would have professed greater interest in the development of character than in intellect. Since that time, the pendulum has swung the other way, and most of these institutions place primary emphasis on the intellectual development of their students, with secondary attention to the development of character and a capability for informed, thoughtful citizenship. Clearly, an institution should select its goals on the basis of the socially desirable and morally right, as well as what is educationally most efficient.

Does the Chemistry Faculty of a Liberal Arts College Establish Independent Standards for Evaluation of its Productivity?

Many college chemistry departments (and this would include essentially all of those generally recognized to be most successful) actually evaluate their own performance in quite different terms than those related to the traditional values of a liberal education. They function as preparatory institutions for the graduate schools, and tend to judge their success in terms of the fraction of their alumni who go on to graduate study, and who win the competitive fellowships to support this study. Consequently, the goals of these undergraduate departments have in fact been adjusted to conform to the expectations of the universities and the professional societies. This shift of goals is also reflected in the increased attention accorded to research and publication by faculty members in these institutions. In the process of meeting these new standards, the undergraduate colleges have paid the price of increased rigidity in curricula and course requirements.

Does Pressure on the Graduate Program Justify Moving Traditionally Graduate-Level Courses into the Undergraduate Curriculum?

One clear trend in undergraduate education during the past 25 years has been the transfer of courses which were formerly regarded as part of the graduate program into the undergraduate years. This has been rationalized in part as a response to the rapid development of chemistry, and in part by the supposed improvement in chemistry courses available at the high school level. In fact, it appears that the abilities and the quality of the secondary school backgrounds of students at the highly selective colleges are rising, but the high school preparation of most students has not improved sufficiently to justify omission of the introductory course in most colleges. The Conference was unable to obtain statistical information which would confirm these qualitative impressions of contemporary high school preparation for chemistry courses.

Possibly the major curriculum pressure on undergraduate institutions arises as a result of the increase in time required to earn the Ph.D. degree in some graduate departments. For example, this has increased in the past ten years from 7.5 to 10.5 semesters average elapsed time to earn the doctorate in chemistry at one major institution. A number of reasons have been suggested for this increase. Better financial support for graduate students has reduced the pressure on them and their advisors to invest extra effort to complete their thesis research quickly. Furthermore, the standards of originality and accomplishment set for an acceptable Ph.D. thesis have been rising slowly. The graduate schools see a possibility to reduce the elapsed time for

graduate study by moving some of the courses traditionally offered as part of graduate training to the undergraduate years.

Is the Liberal Arts College Chemistry Curriculum Becoming Too Inflexible?

A consequence of the effort to meet the demands of the graduate schools is that the undergraduate curricula of chemistry majors have become strongly biased toward chemistry and supporting courses in physics and mathematics, and these students have little freedom to choose courses in other areas which interest them. Thus, there is serious question whether the colleges are meeting their own professed educational objectives in offering these curricula designed to fulfill the increased expectations of the graduate schools. In many schools, these pressures have discouraged the free innovation in curriculum which should characterize a good undergraduate liberal arts college, and which should be a major contribution of these instutions to the educational process. If a college can do no better than blindly imitate the undergraduate programs in the universities, this suggests a bankruptcy of educational ideas which calls into question its continued existence, particularly in view of the high operating cost per student served.

A curriculum designed to provide the most expeditious professional training of chemists may not be a very effective device for developing the human resources of the student. Some students have defined their personal and career goals so narrowly that they prefer to move forward with a professional education as rapidly as possible. Others will prefer a program which offers greater opportunities to sample the variety of human intellectual experiences, even at the price of an additional year or more of study to reach the doctorate. It seems clear that students of this type have been repelled by the inflexibility of the undergraduate chemistry curriculum. These students may be uncertain about their own capabilities and desires, and many of the best of them find it distasteful to make an early choice of career and to narrow their educational interests to those dictated by this choice. This group includes many of the most creative students now in college. Only the most mature students are willing to make this choice so early, and they never will be more than a minority of the student body in the age range usual to American educational institutions. For these reasons, it seems to this Conference that the attempts of some graduate schools to require the same quite intensive undergraduate education in chemistry of all entering students is unwise and mistaken. No disgrace should accrue to a student who has performed capably in a minimum undergraduate curriculum, and thus requires substantial remedial work at the advanced undergraduate level when he enters graduate school. Such a student clearly can remedy his deficiencies if he has the enthusiasm and intellectual ability, at the price of some additional time to earn the doctorate.

Do the Graduate Schools Really Know What They Want in the Baccalaureate Training of Chemists?

Most of the questions which are being raised about the quality of undergraduate education in the liberal arts colleges originate in the graduate schools. Still, for every department willing to single out for criticism the students who come to it from the colleges, another can be found which claims to prefer graduates of the better colleges as candidates for graduate study. In no case has data been collected over a long enough period or involving a large enough number of students to afford solid evidence on the adequacy of the undergraduate education currently offered by the colleges. The replies from chairmen of graduate departments in response to the questionnaire circulated by Professor Scott are inconclusive on this point. There clearly is a large variation in the willingness of graduate departments to tolerate repair of deficiencies in incoming students. There is near unanimity that any student who survives his first year of graduate study with satisfactory grades can expect to earn his doctorate. There also is a general opinion that the experience of participation in an undergraduate research program provides major help to a student who is making the transition between undergraduate and graduate study in chemistry.

PROPOSED ALTERNATIVES TO THE TRADITIONAL PROGRAM

As a consequence of a penetrating, realistic appraisal of its resources, a college may decide that it cannot offer independently a full program to prepare students for graduate study in chemistry. Furthermore, the demands of a program of this sort are now so heavy, and will increase so rapidly in the future, that it is likely that many institutions will be unable to offer such a program over the long term. The participants in the Conference suggested some possible remedies for the problems of these colleges which are considered in the remainder of this section.

Institutional Cooperation

One course open to those institutions which find themselves unable to offer an adequate full major program in chemistry would involve cooperative arrangements among colleges within reasonable travel time of one another. This cooperation would require a pooling of resources in such a manner that each participating institution would make the contribution best within its capabilities to the overall program. Thus, each institution might employ one faculty member capable of offering one of the advanced elective courses in chemistry. Its students would go to other institutions in the cooperating group for other courses of this type, and these courses would be cross listed in all of their catalogues. This cooperation could also take the form of instrument centers which would provide access by students and faculty to those instruments, including a computer, which would be too expensive for the schools to obtain individually. In addition, these cooperative arrangements could extend to the libraries of the participating institutions.

Somewhat similar cooperative arrangements might be instituted with a local university. The university might provide laboratory or library facilities beyond the reach of the college. Cooperation should provide opportunity and facilities to combat faculty obsolescence in the college, and to offer advanced courses not available to the colleges involved. In this case, it would be desirable that the undergraduate institutions search for ways in which the arrangement could benefit the chemistry department in the university, so that it would not be a one-sided affair with all of the interest and benefits on the part of one of the partners.

Selective Specialization

Another alternative would be to offer courses or programs in limited or special applications of chemistry. Some schools could create programs appropriate to the geographic area in which they operate. It may be necessary to sell these programs to their students, because students from more limited backgrounds tend to be unaware of the great opportunities available today in hybrid fields. Possibilities of this sort would be chemical oceanography, combined chemistry-business programs, or environmental studies which involve heavy preparation in chemistry.

Establishment of Limited Masters' Program

Several of the strong colleges have over the years offered master's degree programs which have contributed to the strength and breadth of their upperclass offerings. Some other institutions might gain increased strength through similar master's programs designed to prepare graduates of colleges with limited course offerings for entrance to graduate work. This, however, is regarded as a risky and uncertain venture, in view of the decline in prestige and acceptability of the master's degree over the past 25 years.

Established Limitations in Course Offerings

An institution may decide that its own limited capabilities and the restricted opportunities for cooperation with other institutions within reasonable travel time preclude offering a full program for the undergraduate major in chemistry. It is far better for these institutions to recognize this situation and to face it honestly, than to take unfair advantage of the expectations of their students by offering an inadequate program. It would be to the advantage of these institutions to offer two or three years of work in chemistry at an acceptable level, and not attempt to present a full curriculum. Students in these institutions would then be well prepared to transfer to another college or a university to complete their

undergraduate education, and to proceed from there to graduate study. We wish to emphasize the important contribution that the colleges can make to the pre-professional education of medical students and to the liberal education of all students by offering a strong program which is nevertheless incomplete from the standpoint of professional training.

Each college should offer sound training in those areas where this is possible, but it should not attempt to maintain a complete program at the expense of quality. Prospective students must be informed honestly, in the catalogue and personally, of the limitations in the program of the department.

V. RECOMMENDATIONS BY THE CONFERENCE

Participants in the Conference are convinced that it is possible for a liberal arts college to offer excellent undergraduate preparation for training chemists through the Ph.D. degree. However, they are concerned by the evidence that many colleges do not now offer adequate preparation for graduate work, and by their expectation that the demands of the graduate schools will become even more stringent in the future. They are convinced that the undergraduate liberal arts colleges will survive as a class of institution, and that these institutions are valuable to American education. They feel that it is essential for each of these institutions to reexamine its own performance, capabilities, and goals as realistically as possible. These institutions pursue a wide range of goals. They have useful functions to perform other than the education of professional chemists. These functions are worthy of more serious attention than they have received in the past, both from the colleges themselves and from professional chemists.

However, since college chemistry departments are concerned about the present and future preparation of students for graduate work, the principal set of recommendations deals with the problems of assuring quality in this function. A program of study in a liberal arts college should provide breadth through exposure to several fields. In addition, it should involve the study of one field, the major, in depth. If the institution chooses to offer a major in chemistry directed towards adequate preparation of chemists for entrance to graduate school with full graduate standing, attention must be given to the following recommendations which deal with faculty, instrumentation, and curriculum.

FACULTY

The central problem for the undergraduate liberal arts colleges will be selecting, holding, and avoiding obsolescence in an adequate faculty. The Conference feels that a professionally active faculty of four is the minimum required for an adequate program to prepare students for graduate study in chemistry in a liberal arts college of approximately 500 men. For each additional 200 male students at the institution, there should be at least one additional staff member. (We state these requirements in terms of male students because the enrollment of women in chemistry courses tends to be lower – frequently much lower – than that of men.) The faculty should be selected to represent interests over a range of specialized fields; the minimum representation for an adequate undergraduate course program demands at least one faculty member trained in modern mechanistic organic chemistry and one in molecular level physical chemistry, among the four faculty members.

The academic efficiency of this faculty should be enhanced by providing adequate subprofessional help. In the past, the most important form for this help was adequate stock room and secre-

tarial service. In the future, we feel that the demands of adequate instrumentation will require at least the part-time services of an electronics technician, a machinist, and a glassblower. It is most important that this help be made available on a scale which will remove the burden of subprofessional duties (including routine administration) from the faculty, and free them to discharge the professional obligations which they must meet in order to maintain their competence.

Research opportunity at the institution is highly desirable both as a device to attract and hold new faculty members and to avoid obsolescence in older ones. Research in the liberal arts colleges should be viewed in a broad sense to include all forms of scholarly work. One possible avenue of professional activity for faculty members in the liberal arts colleges is the preparation of critical reviews. Textbook writing offers another direction for their efforts, and surprisingly little of this is done by faculties in the colleges. All forms of scholarly activity should be planned and carried out in a manner designed to involve maximum student participation. This both arouses interest and affords experience which is valuable to students in selecting a graduate school and choosing a research problem there.

We do not wish to minimize the difficulties in carrying out a viable scholarly program at an isolated liberal arts college. The first of these is free time. It is clear that faculty members in a department with fewer than four members will be too hard pressed by the demands of teaching, committee work, laboratory supervision, and so forth, to invest the necessary time and energy in scholarly work. There are also difficulties in providing adequate instrumentation and library facilities, and of interaction with other professionals with interests in the same area. Finally, there is a problem of motivation, particularly for those faculty members who are long out of graduate school. We urge both the Division of Chemical Education and the Advisory Council to search for ways to help active faculty members to keep up with progress in the field of chemistry. Serious attention should be given to refresher courses offered during the academic year which provide specially designed course work (*not* conventional graduate courses) for faculty members who are on leave from liberal arts colleges.

We also recognize the difficulty faced by many faculty members in starting a research program if they are long out of graduate school. Various summer institutes, college faculty research participation programs, and postdoctoral fellowships all can afford some help in this direction. In addition, the visitors provided by the Visiting Scientist Committee of the ACS Division of Chemical Education and the Division's Consultants Service can provide suggestions for getting started. There is a clear need for financial support for faculty-student research in undergraduate colleges in which the work has not reached a level which attracts support through the normal channels which provide research grants.

The gap between the professional opportunities open to faculty members in the colleges and in the universities is now enormous and it is growing. University faculty members have more time, better sabbatical leave programs, more subprofessional support, elaborate instrument and library resources, and more research help. All of these facilitate the professional development and research output of the university faculty member. The problem of the colleges is to become more competitive in affording professional opportunity for the faculty, while at the same time preserving their devotion to the conscientious discharge of teaching duties at the undergraduate level. Mere imitation of the universities is not adequate here; the colleges need to make original contributions to the solution of their problems. In the long run, it appears inevitable that teaching loads in the colleges must be drastically reduced to remedy some of their competitive disadvantage in hiring faculty.

INSTRUMENTATION AND ITS MAINTENANCE

We recognize a need to introduce the student to various instruments, both because this is attractive to the students, and because of the need to teach chemistry as it is actually practiced. These instrument requirements are not limited to advanced courses or faculty-student research.

Student models of infrared spectrophotometers and vapor phase chromatographic apparatus should be available in the elementary organic chemistry laboratory, together with standard taper ware in which to carry out reactions. The physical chemistry laboratory clearly demands an exposure to spectroscopy in some depth.

At the level of advanced elective courses and senior research, every student should have detailed experience with a high grade instrument which operates in one region of the electromagnetic spectrum. His experience should include the operation, checking, adjustment, and evaluation of reliability of the instrument. He should know something about how it is calibrated. In addition, each student should understand the significance of spectra recorded in other regions, and have practice in the interpretation of these spectra. The selection of the instrument which is available in a department can be based upon the research interests of members of that department. This research interest will guarantee that at least one faculty member will have adequate background in the use of that instrument for instructional purposes. More than one of the conventional recording spectrophotometers will become desirable as the faculty of a department expands beyond four members. These additional instruments should also be chosen in accord with the research interests of the department members.

In addition to the training in spectroscopy already outlined, each institution should provide its chemistry majors with exposure to the programming and use of digital computers. These devices of course have the advantage that they can be accessible at remote locations through a local console.

Members of the Conference disagreed about the desirability of providing chemistry majors with instruction in electronics. They also disagreed about the need for a nuclear magnetic resonance spectrometer. It seems clear that the minimum instrument requirements stated above will grow as instrumentation develops, and that expectations will rise as lower cost instructional models of instruments appear. For example, NMR spectrometers in the $20,000 price range are now available. It can be hoped that still less expensive devices of this type will become available and more widely used in the future.

We wish to emphasize that the acquisition of major instruments adds to the burdens of the chemistry faculty. Each of these instruments poses demands in installation, operation, maintenance, and demonstration to students. When many of them become available it will become necessary for the institution to provide an electronics technician who can replace faculty in these functions. These instruments have a clear value in attracting student interest and in attracting and holding faculty members. We question how far they can be justified financially for a limited use by a small number of students. We also have no clear answers to the problems of student use by large undergraduate classes. It seems clear that contact with the instruments at this level will be largely confined to watching demonstrations, and interpreting the spectra.

CURRICULUM

Curriculum problems are not confined to the undergraduate liberal arts colleges. Many of these problems are common to these institutions and the universities. There was considerable feeling among Conference members that rapid changes in chemistry have outpaced normal evolution of the conventional curriculum. We may now need a completely rethought and redesigned curriculum. Two isolated examples of the type of thinking which may be necessary are the curricula now in operation at California Institute of Technology and at Earlham College.

Adequate curriculum revision may require abandoning the traditional course structure of chemistry. There is a need to reexamine the content of the curriculum in terms of essential topics, and to base planning on these. Without this, the emotions connected with vested interests in the conventional fields of chemistry will serve as a strong deterrent to change. Consequently, the Conference strongly encourages the Advisory Council in its efforts to provide a topical analysis of the undergraduate curriculum. A restatement of the requirements of a curriculum in topical terms will encourage innovation by individual schools of a sort which has been sadly lacking in years past. In particu-

lar (and probably as a result of heavy demands upon faculty time), the contributions of college chemistry departments to imaginative curriculum change have been far less than might be expected from these institutions where the undergraduate program has highest priority.

Curriculum needs will vary with the institution, its student body, and its faculty. We agree that in all cases courses which offer modern mechanistic organic chemistry and molecular physical chemistry must serve as the required basis for advanced courses. Each undergraduate liberal arts college should offer a number of advanced courses in areas which are determined by the interests and competence of its faculty. We note that these requirements demand Ph.D.-level staff, and if they involve advanced training in physical chemistry, require strong support from the physics and mathematics departments.

It is a fact that strong chemistry departments have developed in institutions with little to offer in the supporting disciplines of mathematics or physics. In part this is because chemistry embraces a very wide range of subdisciplines, some of which have been more descriptive and qualitative and have demanded less from these supporting departments. It seems clear that the demands for a more quantitative approach are increasing in all of the subdisciplines of chemistry, and that as a bare minimum, the institution must offer at least one year of solid training in both mathematics and physics. Adequate preprofessional education for modern physical chemistry will demand much more than this. We feel that it would be short-sighted to condemn those departments which do not have strong support from their mathematics and physics departments. For example, it appears that both the fields of organic and biochemistry will continue to afford professional opportunities for students who lack strong preparation in mathematics and physics. We also point out that most administrations exercise a leveling influence within an institution. If the chemistry department becomes substantially stronger than other areas in the science division, the effort will be made to turn any increase in support to the improvement of the weaker departments. Since these are necessary to broadly based training in chemistry, we feel that the chemistry departments should be interested in this improvement and should encourage it.

THE ROLE OF THE A.C.S. COMMITTEE ON PROFESSIONAL TRAINING

Recommendations of the Committee on Professional Training have provided a useful standard for departments in evaluating and improving their own programs, and to students in selecting institutions to attend. The value of standards is reflected by the fact that over 160 undergraduate liberal arts college departments now (in 1968) have programs which have been approved by the CPT. This is in stark contrast to the weak college programs in physics, which has not had a comparable professional evaluation. However, it seems clear that the present standards of the Committee on Professional Training may have inhibited curriculum innovation and revision. The undergraduate colleges have failed to take advantage of that flexibility which is permitted by the CPT, and some have also used certification requirements to force students into a rigid curriculum pattern. This restrictive use of the CPT program has driven a significant number of able and thoughtful students out of chemistry. There must be more flexibility to adapt programs to individual student interests which combine the field of chemistry with physics, biology, oceanography, and so on. We feel that publication of the annual departmental tabulation of certified graduates (which is used by the American Chemical Society only for membership purposes) is a mistake, because it may encourage a restrictive curriculum and serves no useful purpose.

The needs of institutions which cannot offer full programs which meet the standards for professional training should be served by a committee analogus to the Committee on Professional Training with equivalent prestige within the American Chemical Society, designed to approve limited programs such as those suggested in the "conclusions" sections of this report. Possibly one such group should set standards for and evaluate programs of this type in both two-year and four-year institutions. The possibility of approval by a group of this sort

would be a major incentive to weaker institutions to study their own capabilities realistically and to offer strong but limited programs within their capabilities.

SURVEY OF NEEDS AND REQUIRED RESOURCES FOR UNDERGRADUATE EDUCATION

It is clear that substantial financial support will be required to implement the recommendations already listed in this report. A fraction of the necessary funds will originate in the colleges themselves. However, most of the development in university chemistry departments since World War II has been made possible by substantial infusion of Federal funds. Most of this effort has been directed to education at the graduate level. We believe that a comparable effort is now justified and necessary for the support and improvement of undergraduate instruction. However, we do not believe that the data now available permit a realistic assessment of the need, the number of institutions which can be helped, or the cost of the program. Accordingly, we urgently recommended that a major survey[10] of the needs, costs, and potential benefits from improvement in undergraduate education be conducted under such auspices and with such personnel that the survey results will command attention and respect. We see two possible ways in which a survey could be conducted.

1. Undergraduate education in chemistry could be studied in institutions of all types, both undergraduate colleges and universities with graduate programs.
2. A broader survey of undergraduate education in all of the sciences could be carried out for liberal arts colleges only. This survey would evaluate the problems, needs, and financial requirements to improve undergraduate education in biology, chemistry, physics, and the other sciences offered in the undergraduate institutions.

(10) We have in mind a study comparable in magnitude and prestige to that on graduate education and research carried out under the chairmanship of Frank H. Westheimer: "Chemistry: Opportunities and Needs," National Academy of Sciences – National Research Council, 2101 Constitution Avenue, Washington, D.C., (1965).

VI. UNSOLVED PROBLEMS

The members of the Conference discussed a variety of other problems, but for lack of pertinent data, were unable to reach consensus opinions. However, these problems are felt to be sufficiently important to justify further study, and we commend them to the attention of AC_3 and academic chemists for this purpose. Answers may be found in the kind of undergraduate instruction provided by the strong liberal arts colleges in contrast to that provided by the universities. However, the probability is that good teaching by well qualified faculty at an institution of *any size* is the most decisive influence in providing answers to these problems.

MOTIVATION OF STUDENTS TO PURSUE A CAREER IN CHEMISTRY:

1. Do most students decide on a chemical career in high school, or do significant numbers make this choice in college, and, if so, at what level in college?
2. Are students who enter college with plans for other careers converted to chemistry? If so, is the attraction due to the subject itself or the chemist the students meet in the classroom or laboratory?
3. Why do so many intended science majors change to other careers? At what level is the attrition greatest and why? What is implied by the fact that these losses are substantial even in highly selective technical schools where one might expect student abilities and motivation to be optimum for choosing a career in science? Does the typical science curriculum have too stringent academic requirements?
4. What are the social and cultural factors influencing present-day students in choice of career? How are these intensified or mitigated by campus environment, size of student body, family backgrounds, etc.?
5. Is there any correlation between a student's choice of type of institution and the factors of personality and purposefulness which make for success in a scientific career?

METHODS OF SUBJECT MATTER PRESENTATION:

1. How can chemistry be presented as an intellectual pursuit, rather than as a routine application of dull techniques? Does the size (and consequent logistics) of laboratory classes affect this?
2. How can the inspirational and motivational presentation of chemistry, particularly at the beginning level be improved?

CONSEQUENCES IN INFLEXIBILITY IN CURRICULUM

1. How inflexible must a course sequence be in terms of prerequisites?
2. Are students lost permanently to some fields (e.g. chemical physics) if they fail to start early in the prescribed course sequence?

EVALUATION AND REWARD OF FACULTY COMPETENCE

1. What are useful measures of staff competence at colleges?
2. Is it possible to reward good teaching at universities?

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Representatives of seven additional liberal arts colleges were invited to participate in the conference, and six representatives of private and government granting agencies also were invited as observers. They failed to reach the Chicago area when transportation facilities were put out of service by a 23 inch snowstorm on the eve of the conference.